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Lessons in urban monitoring taken from sustainable and livable cities to better address the Smart Cities initiative

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ABSTRACT

In this paper we put forward two ideas for monitoring the Smart Cities initiative in a better way.
In developing the first idea, we study past and on-going initiatives in the field of sustainable cities and livable cities and their respective monitoring indicators to demonstrate that not only is a set of indicators needed for efficient monitoring, but also a final synthetic or aggregative index to visualize the initiative's achievements. Specifically, we propose the construction of synthetic indices using principal component analysis (PCA). The second idea attempts to anticipate the changes needed, especially with regard to data collection, to be introduced in current monitoring practices to assess a city's "smartness" accurately. We propose the use of real-time data instead of historical statistics as the basic information with which to construct a set of indicators to explain the initiative. A final index summarizing Smart Cities' real-time set of indicators is suggested in the conclusion.
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1. Introduction: on the need for a synthetic index to visualize the monitoring of urban strategies

It can be said that urban monitoring started with the Earth Summit of 1992, a pioneer event in promoting the role of cities on the road to sustainability. Out of the summit came the so-called Aalborg Charter, which began the assessment of cities' sustainability. By 1995, more than 1200 cities all over the world had ratified the charter. The main agreement reached by the signatories was to draw up their own Local Agenda 21, consisting of a set of indicators to monitor sustainability. From 1995 and over a period of approximately ten years a number of cities did this. Since 2006, however, sustainability monitoring has decreased considerably. In our opinion, the lack of a synthetic index summarizing the overall set of sustainability indicators is the reason behind LA 21's failure, a claim which is analyzed in the following section.

Concurrent with the start of the Local Agenda crisis, in 2005, a new set of global indicators appeared. Quality of life indicators were proposed as a way of assessing a city's livability. The promoter of this new urban monitoring was a private corporation, Mercer, a human resources and related financial services consultancy, with its headquarters in New York City. Mercer is the world's largest human resources consultancy, operating in more than 40 countries. Prior to launching its livability monitoring indicators and index, the so called Mercer's Quality of Living Reports, the firm was well-known for its ranking of cities in terms of cost of living, and its list of the world's most expensive cities for expatriate employees. Mercer's quality of life reports are published on a yearly basis for 221 major cities all over the world. All its surveys are updated yearly. Besides Mercer's there is another measure of livability accepted world-wide: The Economist Intelligence Unit's quality-of-life index. Indicators and the final index were first calculated in 2005 and included data from 111 countries. Unlike Mercer's, The

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Economist index ranks both countries and cities, making use of Mercer's data for cities. The Intelligence Unit is an independent company within The Economist Group, a world leader in the field of financial information. The unit provides tailored advisory, management and analysis services to companies. It is known for its e-readiness index (concerning the effective use of ICT technologies to boost countries' economies and welfare provision) and democracy index (a measure of the level of democracy in both UN and non-UN countries).

Although both Mercer's and The Economist's sets of indicators and final indices have a shorter history, they look more promising than local agendas. Both summarize a combination of subjective life-satisfaction and objective quality of life indicators in an aggregated index which makes their well-known rankings of countries and cities possible. The need of synthetic indices is not only for comparison matters out of a certain ranking. In our opinion, in today's era of information excess it is crucial to synthesize the large amounts of available information in small but representative visualizations, and both Mercer and The Economist Intelligence Unit seem aware of that when drawing up their indices. A proof that quality of life indices are successful is that middle-sized cities not included in these reports produce their own quality of life indicators and indices, and the number of them doing so is growing every year. This is exactly the opposite of what has occurred with local agendas that assess a city's sustainability. We take a deeper look at the success story of quality of life indices in the second section of this paper.

In recent times the Smart Cities initiative has expanded all over the world. It was around 2009 when the concept began to be globally understood as the target for any city to achieve, no matter what its size. The initiative developed out of the previous experiences of measuring environmentally friendly and livable cities, embracing the concepts of sustainability and quality of life but with the important and significant addition of technological and informational components. Reliable indicators do not yet exist to measure how “intelligent” cities are, and neither does a summarizing index, but interest in the initiative is growing and it will not be long before the worlds of academia, business and government start to take notice. Besides the proposal we make about the use of real-time data to develop a Smart Cities set of indicators – learning from the previous experiences of sustainable cities and livable cities – we propose the elaboration of a synthetic indicator to summarize a city's “intelligence” or “smartness”. In the third section of this paper we explain the different sources of real-time data available for developing the latest generation of indicators for monitoring a city's smartness. The conclusions recap on the proposal for a final synthetic index of the smart city set of indicators, to make it possible to easily visualize a city's steps towards “smartness”.

2. Analyzing past and on-going initiatives

2.1. Learning from the Sustainable City and the problems with the LA 21 set of indicators

Local Agendas 21 were conceived of as a sustainability agenda based in the principles of urban ecology [1]. From the origins of the sustainability movement, sustainable development was projected as an activity best generated and most appropriate at a local scale. This localization of the phenomenon was central to the design of the agendas [2]. Their local character resulted in their application not only to big and medium sized cities but also to small towns in non-developed countries [3]. LA 21s have a proven capacity to enhance sustainability and the quality of the urban environment for the benefit of citizens, but the road to sustainability through LAs has only been in existence for 10 years. In our opinion, the lack of a summarizing indicator giving information about a city's overall sustainability level, thereby allowing comparisons and rankings between cities, has been their big mistake.

Since the beginning, LA 21 contained a standard set of indicators with few variations when it was applied locally. We exemplify the LA 21 set of indicators and our proposal for a synthetic indicator using the city of Barcelona, in Spain.

Principal component analysis (PCA) has been demonstrated to be a very useful technique with which to synthesize sets of monitoring indicators. PCA is a mathematical procedure that uses a linear transformation to convert a set of correlated variables into a set of linearly uncorrelated variables named *principal components*. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance and each succeeding component in turn has the highest variance possible. A reduction of data dimension can be obtained while substantial information is retained in the new data set. Stated another way, the ratio of information to the dimension of the new data set is increased. In addition to the reduction of dimension, PCA models can be utilized to construct two statistics frequently used in monitoring processes, the Q-statistic and the Hotelling's T2 statistic. The Q-statistic corresponds to the non-modeled, supposedly non-informative part of the data set. Therefore, this measure shows the lack of fitness of a (new) observation for the model. The Hotelling's T2-statistic is the squared distance from the projection of a (new) observation onto the center of the model.

We can find some significant examples of the application of PCA in the urban context. Wong [5] uses PCA to examine the relationships amongst a set of indicators defining local economic development (LED). Based on a conceptual framework of 11 factors widely perceived to be the major determinants of local economic development, 29 indicators were identified to measure these factors. The author, besides examining the structure of relationships amongst the LED indicators compiled, used PCA to explore the spatial patterns emerging from the analysis. A series of multiple regression models were then calibrated to investigate the relative strengths of relationships between the LED indicators and suggested performance variables. Still in the area of urban economics but turning to urban functional analysis, Chen et al. [6] used principal component analysis, cluster analysis, and location quotient methods to analyze the economies and industries of cities in the Xinjiang region of China, assessing factors such as urban scale, growth pole level, specialization sectors and industry gradients. In the field of real estate economics, Li [7] aimed to solve contradictions between the certainty of fixed reference land prices at a certain time point and the uncertainty of land price changes, which lead to difficulties in the application of reference land prices using principal component analysis to select the main factors affecting land prices.

Focusing more on environmental monitoring, Liu et al. [8] utilized PCA methods to perform a qualitative and quantitative analysis of the spatial and temporal distribution of

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